California High-Speed Train Project

TECHNICAL MEMORANDUM

Design Life
TM 1.1.2

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Prepared by

for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memorandums. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager or the System Integration Manager.

System Level Technical Reviews by Subsystem:

Systems: *Signed document on file*______________ 4 May 09
Eric Scotson Date

Infrastructure: *Signed document on file*______________ 18 May 09
John Chirco Date

Operations: *Signed document on file*______________ 28 May 09
Paul Mosier Date

Maintenance: *Signed document on file*______________ 28 May 09
Paul Mosier Date

Rolling Stock: *Signed document on file*______________ 8 May 09
Frank Banko Date

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ABSTRACT

This technical memorandum assesses and recommends the minimum design life - the period of time for which high-speed train design elements will perform while meeting minimum specifications under a particular maintenance regimen - for the permanent and temporary infrastructure and systems elements required to design and construct the California High-Speed Train Project (CHSTP). Design life will be used to advance the preliminary design, develop the system's maintenance activities and frequency, and inform design and development standards. This technical memorandum may also be used as a baseline document to develop and assess alternate materials, operational and maintenance requirements, procurement methods, and cost comparisons.

The minimum design life for the CHSTP will be based on precedent: the design lives for existing or planned high-speed train systems worldwide and major U.S. transportation infrastructure projects. Factors which influence the design life requirements of various key elements of infrastructure and systems, including difficulty and cost to modify and replace, technological obsolescence, capital and maintenance costs, safety and impact on performance and reliability, will be considered qualitatively in establishing design life requirements for the CHSTP. With system interdependencies, all elements of the high-speed train system must conform to their respective design life requirements in order achieve the design life for the overall system.

The design elements considered in this document are:

<u>Infrastructure</u>

- Civil Works and Track, including:
  - Site, earthwork, line layout, and storm drainage
  - Track, including rails, ties/clips, and ballast
  - Roadway, pavement, and parking facilities
  - Crossings and switches
  - Concrete slab
- Structures, including:
  - Underground structures and tunnels
  - Aerial structures and bridges
  - Above-grade facilities, including passenger stations, ventilation buildings and ancillary facilities
  - Movement joints and bearings
  - Retaining walls
- Mechanical, Electrical, Plumbing, Ventilation and Fire Protection Systems

<u>Systems</u>

- Traction Power Facilities, including:
  - Traction power supply equipment
  - Traction power conduction
  - Overhead contact system (OCS) support structure
  - OCS conduction
  - Grounding, bonding, and lightning protection system
- Train Control Systems, including safety and security monitoring
- Communication Systems, including:
  - Train to central control (SCADA)
  - Passenger, public address
  - Fiber optic cables
- Other technology based systems

<u>Temporary Works</u>

- Temporary tracks, staging facilities, traffic handling during construction

Rolling stock, operations and maintenance facilities are not considered in this document.

1.0 INTRODUCTION

1.1 PURPOSE OF TECHNICAL MEMORANDUM

This technical memorandum establishes minimum design life for permanent and temporary infrastructure and systems elements for advancing the high-speed train project's preliminary design and defining the initial frame of reference for establishing maintenance activities and frequency. This information may also be used to develop and assess design and development standards, alternate materials and designs, operational and maintenance requirements, procurement methods and cost comparisons for the high-speed train project.

1.2 STATEMENT OF TECHNICAL ISSUE

Development of the design criteria for elements of the CHSTP is influenced by the life expectancy and maintenance regimes. This document will assess and recommend the minimum design life for the following infrastructure and system elements:

<u>Infrastructure</u>

- Civil Works and Track, including:
  - Site, earthwork, line layout, and storm drainage
  - Track, including rails, ties/clips, and ballast
  - Roadway, pavement, and parking facilities
  - Crossings and switches
  - Concrete slabs
- Structures, including:
  - Underground structures and tunnels
  - Aerial structures and bridges
  - Above-grade facilities, including passenger stations, ventilation buildings and ancillary facilities
  - Movement joints and bearings
  - Retaining walls
- Mechanical, Electrical, Plumbing, Ventilation and Fire Protection Systems

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  - Fiber optic cables
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<u>Temporary Works</u>

- Temporary tracks, staging facilities, traffic handling during construction

1.3 GENERAL INFORMATION

1.3.1 Definition of Terms

The following technical terms and acronyms used in this document have specific connotations with regard to the California High-Speed Train system.

Capital Cost	The total cost of acquiring an asset or constructing a project.
Design Life	The period of time for which a design element will perform while meeting minimum specifications under a particular maintenance regimen.
Maintenance	Regular activities that are required to support safe operations and the intended use of the high-speed train system such as inspection and correction of deviations from the design along the track.

Acronyms

BART	Bay Area Rapid Transit
Caltrans	California Department of Transportation
CHSTP	California High-Speed Train Project
CTRL	Channel Tunnel Rail Link
DTX	Downtown Extension (Caltrain)
NIST	National Institute of Standards and Technology
OCS	Overhead Contact System
PCJPB	Peninsula Corridor Joint Powers Board
SCADA	Supervisory Control and Data Acquisition
SCRRA	Southern California Regional Rail Authority
TGV	Train à Grande Vitesse
THSR	Taiwan High Speed Rail
TSI	Technical Specifications for Interoperability
TVM	Ticket Vending Machine

1.3.2 Units of Measure

The California High-Speed Train Project is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the United States, and are also known in the US as "English" or "Imperial" units. In order to avoid confusion, all formal references to units of measure should be made in terms of U.S. Customary Units.

Guidance for units of measure terminology, values, and conversions can be found in the Caltrans Metric Program Transitional Plan, Appendice B U.S. Customary General Primer (http://www.dot.ca.gov/hq/oppd/metric/TransitionPlan/Appendice-B-US-Customary-General-Primer.pdf). Caltrans Metric Program Transitional Plan, Appendix B can also be found as an attachment to the CHSTP Mapping and Survey Technical Memorandum.

2.0 DEFINITION OF TECHNICAL TOPIC

2.1 GENERAL

Design life defines the expected service life of an element or how long it will perform while meeting minimum specifications under a particular maintenance regimen. It can also refer to the point at which an infrastructure or system element becomes obsolete. At the end of a design life, it is expected that an infrastructure or system element would be replaced, retrofitted or reconstructed.

Design life has direct implications on safety and long-term life cycle costs. Design life standards generally consider initial capital costs, regular maintenance costs and future repair and replacement capital costs. A short design life could reduce the initial capital outlay and may require significant investment relatively quickly to replace project elements past their safe or useful life. Alternately, an extremely long design life may lead to such burdensome initial capital costs that the design becomes infeasible. A long design life may also lead to a higher risk of functional obsolescence. A prescribed design life also defines the frame of reference for establishing maintenance activities and frequency. All elements of the high-speed train system must conform to their respective design life requirements in order achieve the design life for the overall system.

2.2 LAWS AND CODES

There are no federal or state regulatory requirements pertaining to design life. There are no European Commission Technical Specifications for Interoperability (TSI) pertaining to design life.

3.0 ASSESSMENT/ANALYSIS

3.1 PRINCIPLES

In developing minimum design lives for infrastructure and system elements, the following topics are considered:

- Safety – A problem or failure in an element would create an unsafe situation for high-speed train operations, employees, patrons, or the general public
- Relative order of difficulty to modify or replace an element – Construction, cost, operational impact, and other barriers to modifying or replacing an element
- Technological innovation and obsolescence – New innovations leading to necessary replacement of design elements
- Performance and reliability – Impact on high-speed train performance and reliability
- Integrated and interdependent elements – Other high-speed train infrastructure or systems elements require or depend on an element for operation
- Operations – System or element is required to perform for high-speed train operation
- Maintenance – frequency of servicing required for a design element to remain serviceable

Design lives shall consider cases where the replacement or retrofit of one element at the end of its design life would severely impact another element or make it obsolete.

The wear rate of some elements is dependant on the level of high-speed train service provided, such as the number of trains running on tracks or pantographs using an OCS wire. As such, these elements may need to be replaced prior to “standard” design life if they are subjected to higher traffic than provided for in the initial design. These principles impact and influence the design lives used to establish precedent for CHSTP design lives.

3.2 CHSTP DESIGN LIFE ELEMENTS

The design life requirements for the CHSR elements affect the performance criteria for design, operations and maintenance, and consequently impact implementation and operations.

The principles laid out in Section 3.1 support the best practices from Table 3-1 to provide reasoning for the design lives for CHSTP design elements.

CHSTP design elements have different factors which influence design life. Design elements are organized by subsystem and described as follows:

<u>Infrastructure</u>

Most infrastructure elements are relatively established systems that require consistent performance. Technological innovation is unlikely to render this subsystem obsolete prior to the completion of an established design life.

Civil Works and Trackage

Site, earthwork, line layout, and storm drainage: These elements define the fundamental structure of the alignment and all other system elements are layered on top of them. This makes these elements extremely difficult to modify or replace.

Track, including rails, ties/clips, and ballast: These elements are required for safe train operation as they are the actual elements the trains run on. Constant use also leads to significant wear, which impacts feasible design life. Safe operation will require consistent maintenance. Track technology is not expected to change significantly.

Roadway, pavement, and parking facilities: Replacement and restoration of these facilities can be phased to allow for continued system operation. Wear on these facilities will lead to degradation which is difficult to prevent even with continual maintenance. The capital investment required to ensure an extremely long design life may not be warranted due to these factors.

Crossings and Switches: While crossings and switches are only pieces in the system of trackage, they are necessary for safe operations. As complex systems, extended replacement times could seriously impact service. A well developed maintenance regime can extend design life.

Concrete Slab: The difficulty of replacement of concrete slab would lead to significant disruptions in service or the development of parallel routes due to construction and curing times. Because other track elements are dependant on concrete slab, the design lives of these elements should coincide.

Structures

Underground structures: Underground structures present extensive challenges across all factors which influence design life, including difficulty to build, modify, replace and maintain; and other subsystems reliance on a safe and functioning structure. The unavoidable high capital costs of any underground structure require a long design life to contain life cycle costs.

Above-grade facilities, including bridges, stations, ventilation buildings, ancillary facilities: Nearly all of the factors which lead to a long design life for underground structures influence the design life of above-grade facilities. Although maintenance, modification and replacement are slightly easier above ground, the dependence of other subsystems on these facilities, high capital costs, and safety and operations concerns make a long design life beneficial.

Movement Joints and Bearings: Movement joints and bearings are integrated into the system of structures. However, wear and tear on these elements is inherent and providing a design life which coincides with other structural elements may not be feasible. Replacement of these elements can be done without significant disruption to operations.

Retaining Walls: Retaining walls integrate those factors which influence the design life of structures and site and earth works. Replacement and reconstruction has large capital costs, is disruptive to operations and other subsystems, and has safety implications.

Mechanical, electrical, fire protection, plumbing, and ventilation systems: These systems will be required in buildings and structures throughout the alignment. General wear will lead to degradation and require replacement. Improvements to the technology and implementations of these subsystems may occur which may require facility updating. Additionally, replacement or modification of systems may occur while existing systems are still operational making the process easier.

Systems

Traction Power Facilities: Traction power facilities, including power supply stations, high voltage cables, OCS conduction equipment, OCS support structures, grounding, bonding, and lightning protection systems, are essential for any operation of the train and malfunction could be a hazard to not just high-speed train patrons but the general public. As a complex, integrated system which is required for train operations, replacement or modification will be difficult without disruption to revenue service. Degradation due to wear and a risk of obsolescence are also factors in determining design life.

Train Control Systems: Train control systems, including structural safety and security monitoring, are essential for safe operation of high-speed trains. Innovation of these systems is ongoing and likely to continue. Such systems can be expensive and difficult to replace system-wide, especially when introducing a new system into a fully operational railroad.

Communication Systems: Communications systems, including passenger and SCADA systems, like train control systems, are essential for safe, quality high-speed train operation. Also, innovation is likely in these systems as well.

Fiber Optic Cables: Fiber optic cables will run along the alignment in protected, accessible duct banks. As the cables are accessible, replacement and maintenance is fairly simple provided a new redundant system can be constructed while the existing system is operational. Also, technological innovation is likely to lead to improvements or obsolescence.

Temporary Works

Temporary works, including tracks, staging facilities, and traffic handling during construction, are by nature planned for obsolescence. They should be easily modifiable and replaceable, be independent elements and have a relatively small impact on overall system operations, maintenance and safety. As such works are temporary, additional investment to extend their design life is unnecessary.

3.3 EXISTING DESIGN LIFE STANDARDS

Design life criteria used by other transportation agencies and systems were obtained to provide a reference and assessment of the current practice and establish an appropriate design life for CHSTP design elements. Agencies and systems researched include the following:

- Caltrain/PCJPB – Commuter Rail on the Peninsula in the San Francisco Bay Area
- Metrolink/SCRRA - Los Angeles Area Commuter Rail
- Caltrans, State of California Department of Transportation
- Train à Grande Vitesse (TGV), France
- Channel Tunnel Rail Link (CTRL), United Kingdom
- DTX – Downtown Extension of Caltrain into San Francisco's business district (planned)

These criteria are summarized in Table 3-1.

Additionally, other agencies provide a system-wide design life. Instead of defining design life by element, a general overarching design life is used. It is important to note that these systems may have design lives specific to design elements which are not available. System-wide design lives are as follows:

- Taiwan High Speed Rail (THSR), Taiwan – 100 years
- High Speed Train, China – 100 years
- Bay Area Rapid Transit (BART) – Heavy rail transit system in the San Francisco Bay Area – 75 years

Table 3-1 – Design Life for Existing Systems

	CALTRAIN	METROLINK	CALTRANS	TGV (France)	CTRL (UK)	DTX[1]
INFRASTRUCTURE						
Civil Works and Trackage						
Site, earthwork, line layout, storm drainage	50 years	10-100 year storm	NA	100 years	NA	50 years
Track: Rails, ties/clips, ballast	NA	NA	NA	30 to 40 years	NA	NA
Roadway, pavement, parking facilities	50 years	NA	40 years	50 to 100 years	NA	25 years
Ballast	NA	NA	NA	30 to 40 years	NA	NA
Crossings/Switches	NA	NA	NA	100 years	NA	NA
Concrete Slab	NA	NA	NA	NA	NA	NA
Structures						
Underground structures	100 years	100 years	75+ years	100 years	120 years	100 years
Above-grade facilities: bridges, stations, ventilation buildings, ancillary facilities	100 years	100 years	75+ years	50 to 100 years	120 years	50 years
Movement joints, bearings	NA	100 years	NA	100 years	120 years	25 years
Retaining Walls	50 years	100 years	75 years	100 years	120 years	50 years
Mechanical, electrical, fire protection, plumbing, ventilation	NA	NA	NA	NA	NA	50 years
SYSTEMS						
Traction Power Facilities: Power supply stations; OCS support and conduction; Grounding, Bonding and Lightning Protection Systems	50 years	NA	NA	20 to 25 years	40 years	50 years
Train Control Systems including structural safety and security monitoring	25 years	NA	NA	20 to 25 years	NA	25 years
Communication Systems: Passenger, SCADA	25years	NA	NA	20 to 25 years	NA	25 years
Fiber Optic Cables	25 years	NA	NA	20 to 25 years	NA	NA
Other technology based systems	10 years	NA	NA	NA	NA	NA
TEMPORARY WORKS						
Tracks, station facilities, traffic handling during construction	5 years	NA	NA	NA	NA	5 years

[1] DTX system is under design, not an existing system

Note: All design lives listed above assume regular inspection and timely maintenance of the subsystems.

3.4 CHSTP Design Life

Minimum baseline design life for CHSTP infrastructure and systems elements is based on precedent and best practices from existing and planned high-speed rail and transportation systems. Some design elements have been grouped due to element interdependence. In addition, all elements of the high-speed train system shall conform to their respective design life requirements in order achieve the design life for the overall system. Minimum design life requirements are presented in Table 3-2.

Table 3-2 – Minimum Design Life

	CHSTP Minimum Design Life
INFRASTRUCTURE	
Trackage and Civil Works, including: • Site, earthwork, line layout, storm drainage • Crossings and switches • Concrete slab	100 years
With the exception of: • Roadway, pavement, parking facilities • Track, including rails, ties/clips, ballast	50 years 30 years
Structures, including:	
• Underground structures • Above-ground facilities, including bridges, passenger stations, ventilation buildings, ancillary facilities • Retaining Walls	100 years
• Movement joints, bearings	50 years
Mechanical, electrical, plumbing, ventilation and fire protection systems	30 years
SYSTEMS	
Traction Power Facilities, including: • Traction power supply stations • Overhead contact system (OCS) support structure and conduction • Grounding, bonding, and lightning protection system	30 years
Train Control Systems, including structural safety and security monitoring	25 years
Communications System, including: • Train to Central Control (SCADA) • Passenger, public address • Fiber optic cables	25 years
Other technology based systems	10 years
TEMPORARY WORKS	
Tracks, staging facilities, traffic handling during construction	10 years

4.0 SUMMARY AND RECOMMENDATIONS

Design life information for CHSTP infrastructure and system elements establishes minimum requirements for developing and assessing design and development standards and requirements, alternative materials and designs, operational and maintenance activities and frequency, procurement methods and cost comparisons. Design life for high-speed train project elements is based on precedent from the standards of U.S. and international transportation infrastructure and systems.

The recommended design life for Infrastructure and Systems elements are presented in Section 6.0

5.0 SOURCE INFORMATION AND REFERENCES

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6.0 DESIGN MANUAL CRITERIA

6.1 Minimum Design Life for Infrastructure and Systems Elements

Minimum design life for CHSTP infrastructure and systems elements is presented in Table 6-1 and are intended as baseline requirements for use in defining and assessing design and development standards and requirements, alternative materials and designs, operational and maintenance activities and frequencies, procurement methods and cost comparisons. Design life is based on precedent from standards for existing and planned transportation infrastructure. All elements of the high-speed train system shall conform to their respective design life requirements in order achieve the design life for the overall system.

Table 6-1 – Minimum Design Life

	CHSTP Minimum Design Life
INFRASTRUCTURE	
Trackage and Civil Works, including: • Site, earthwork, line layout, storm drainage • Crossings and switches • Concrete slab	100 years
With the exception of: • Roadway, pavement, parking facilities • Track, including rails, ties/clips, ballast	50 years 30 years
Structures, including:	
• Underground structures • Above-ground facilities, including bridges, passenger stations, ventilation buildings, ancillary facilities • Retaining Walls	100 years
• Movement joints, bearings	50 years
Mechanical, electrical, plumbing, ventilation and fire protection systems	30 years
SYSTEMS	
Traction Power Facilities, including: • Traction power supply stations • Overhead contact system (OCS) support structures and conduction • Grounding, bonding, and lightning protection system	30 years
Train Control Systems, including structural safety and security monitoring	25 years
Communications System, including: • Train to Central Control (SCADA) • Passenger, public address • Fiber optic cables	25 years
Other technology based systems	10 years
TEMPORARY WORKS	
Tracks, staging facilities, traffic handling during construction	10 years